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(54) **SEGMENTED SEAL WITH SHIP LAP ENDS**

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(52) **U.S. Cl.**
CPC ***F01D 11/001*** (2013.01); ***F04D 29/083*** (2013.01); *Y10T 29/49321* (2015.01)

(58) **Field of Classification Search**
USPC 277/411, 412, 415, 418, 419, 421; 415/173.4, 173.5, 174.4, 174.5
See application file for complete search history.

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(57) **ABSTRACT**

A segment for a knife edge seal includes an arcuate segment with a first end with a first end surface and a second end with a second end surface. The first end surface and the second end surface are complementary and overlapping when the first end surface and the second end surface interface with ends of adjacent segments.

13 Claims, 4 Drawing Sheets

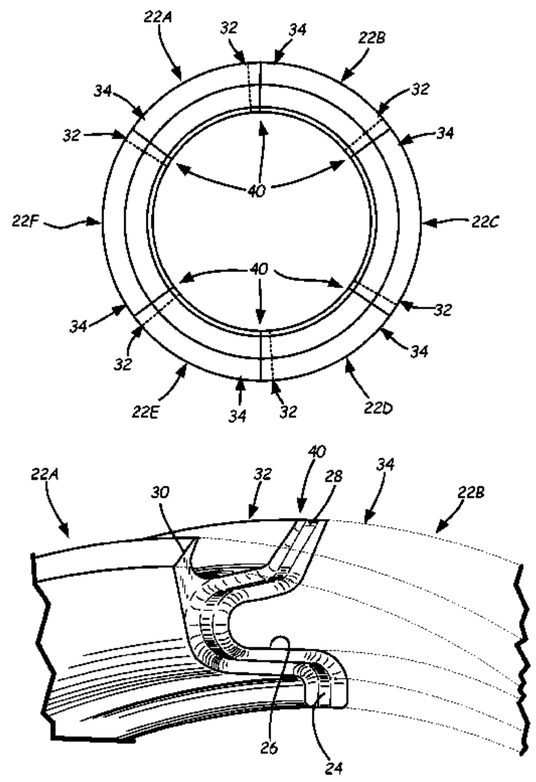
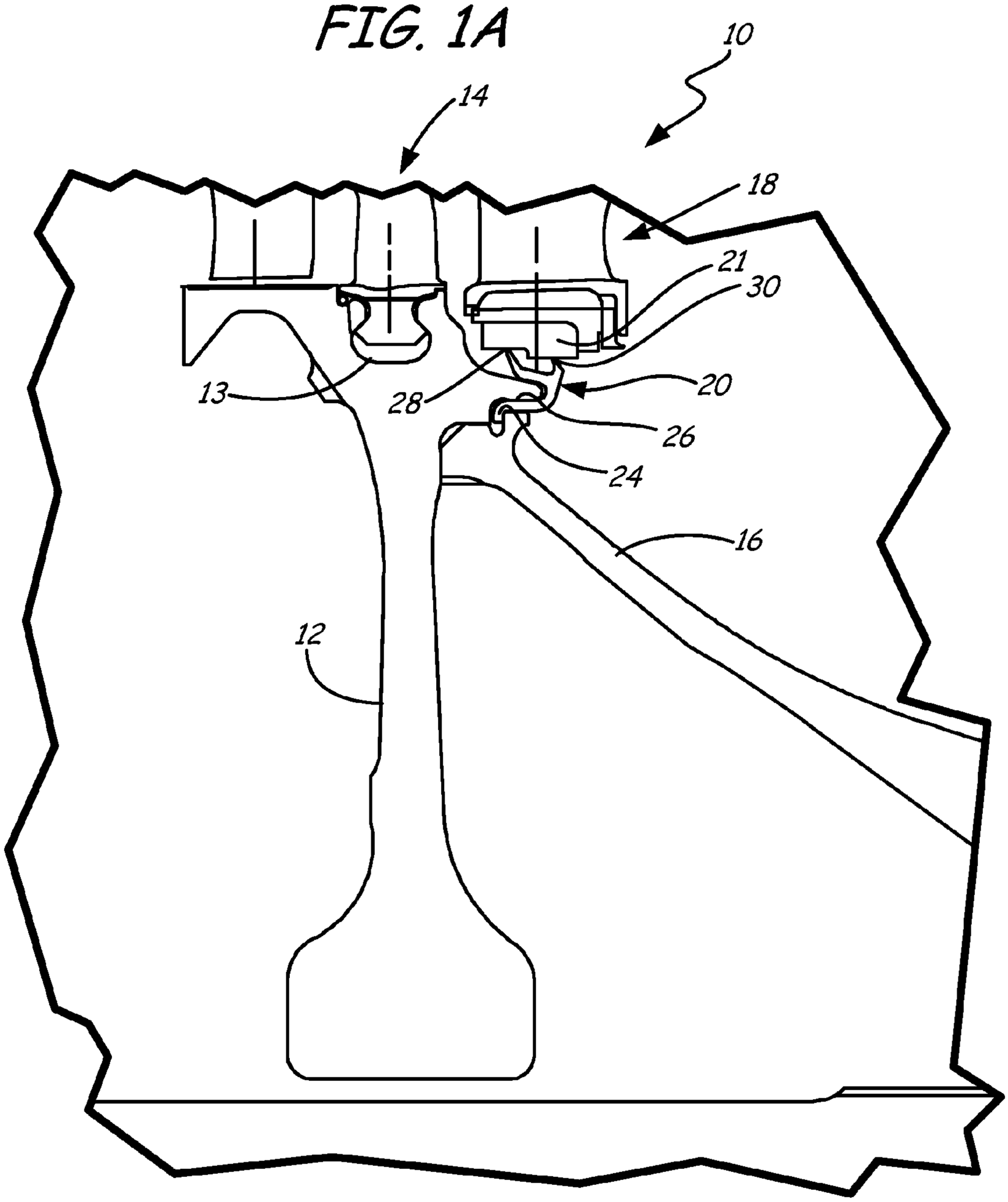


FIG. 1A



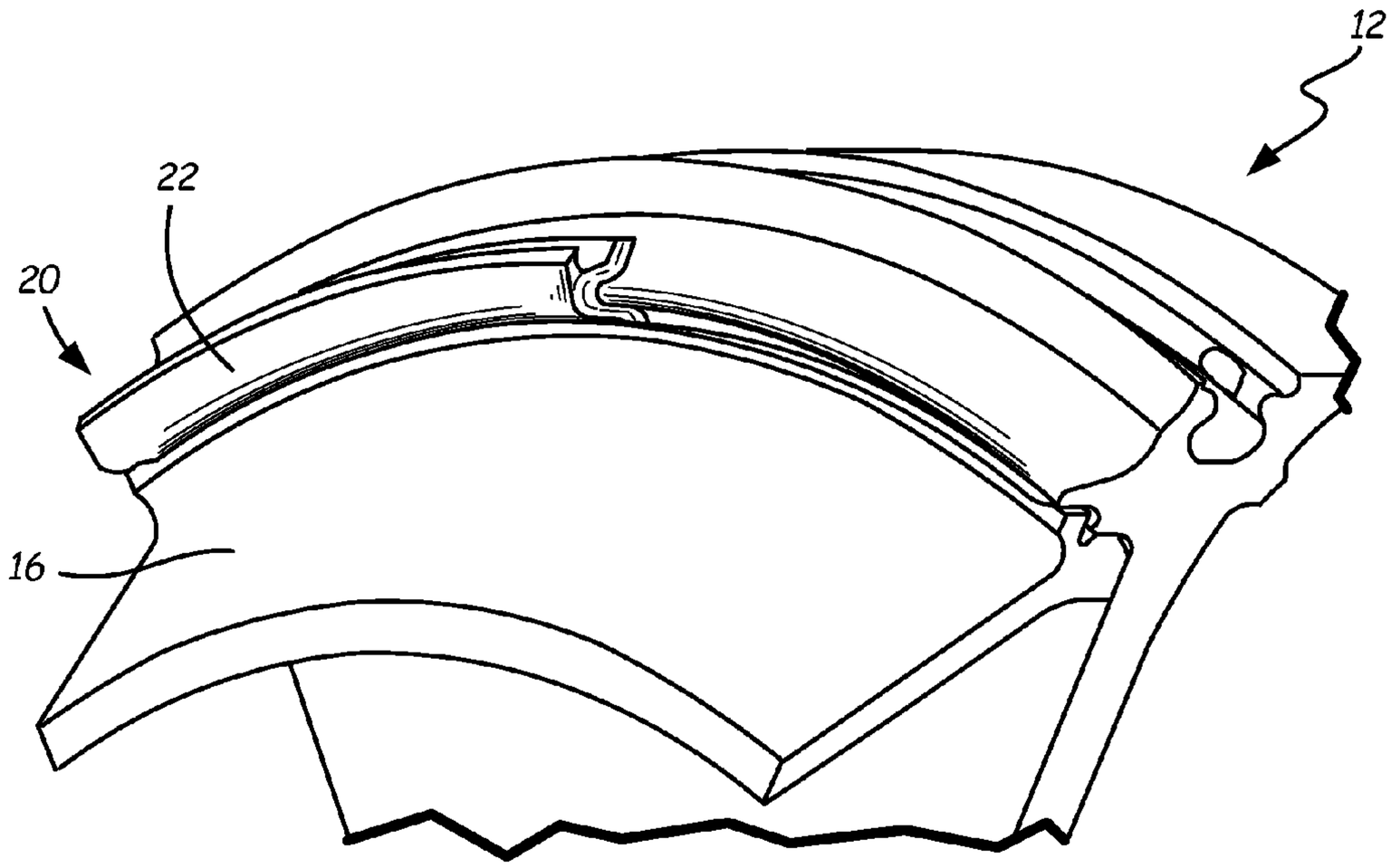


FIG. 1B

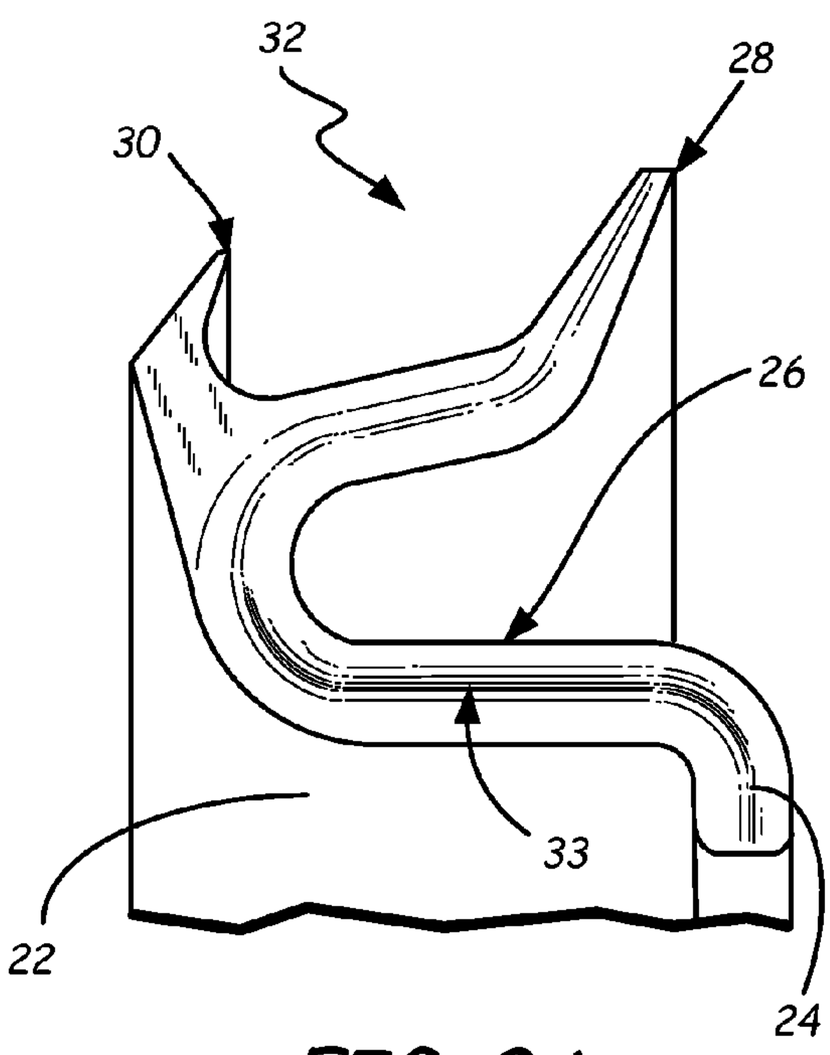


FIG. 2A

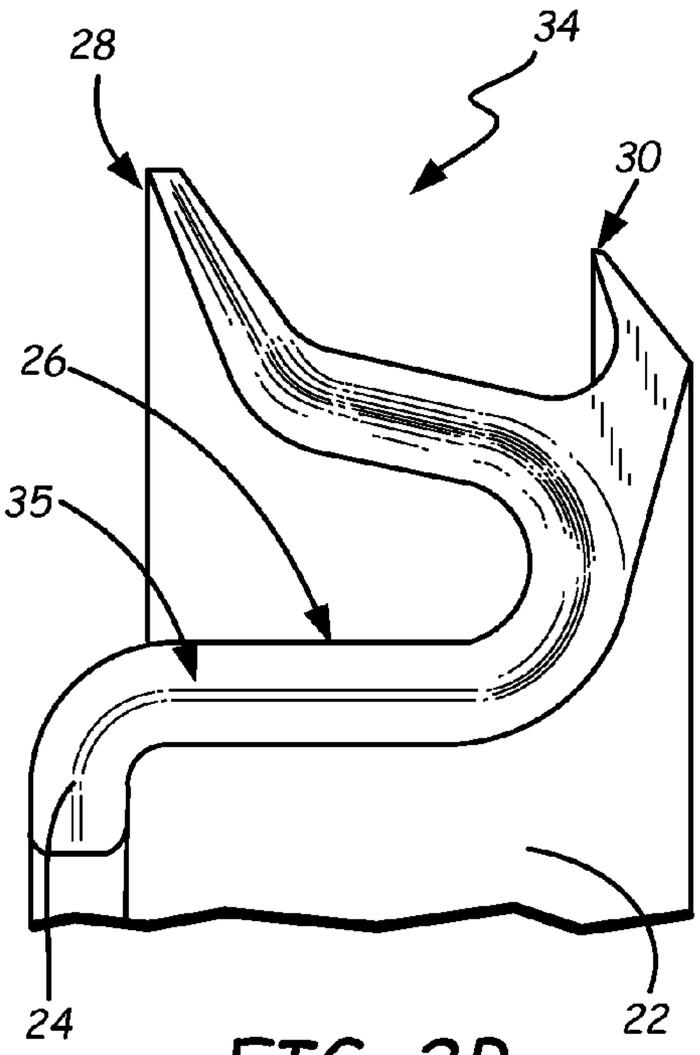


FIG. 2B

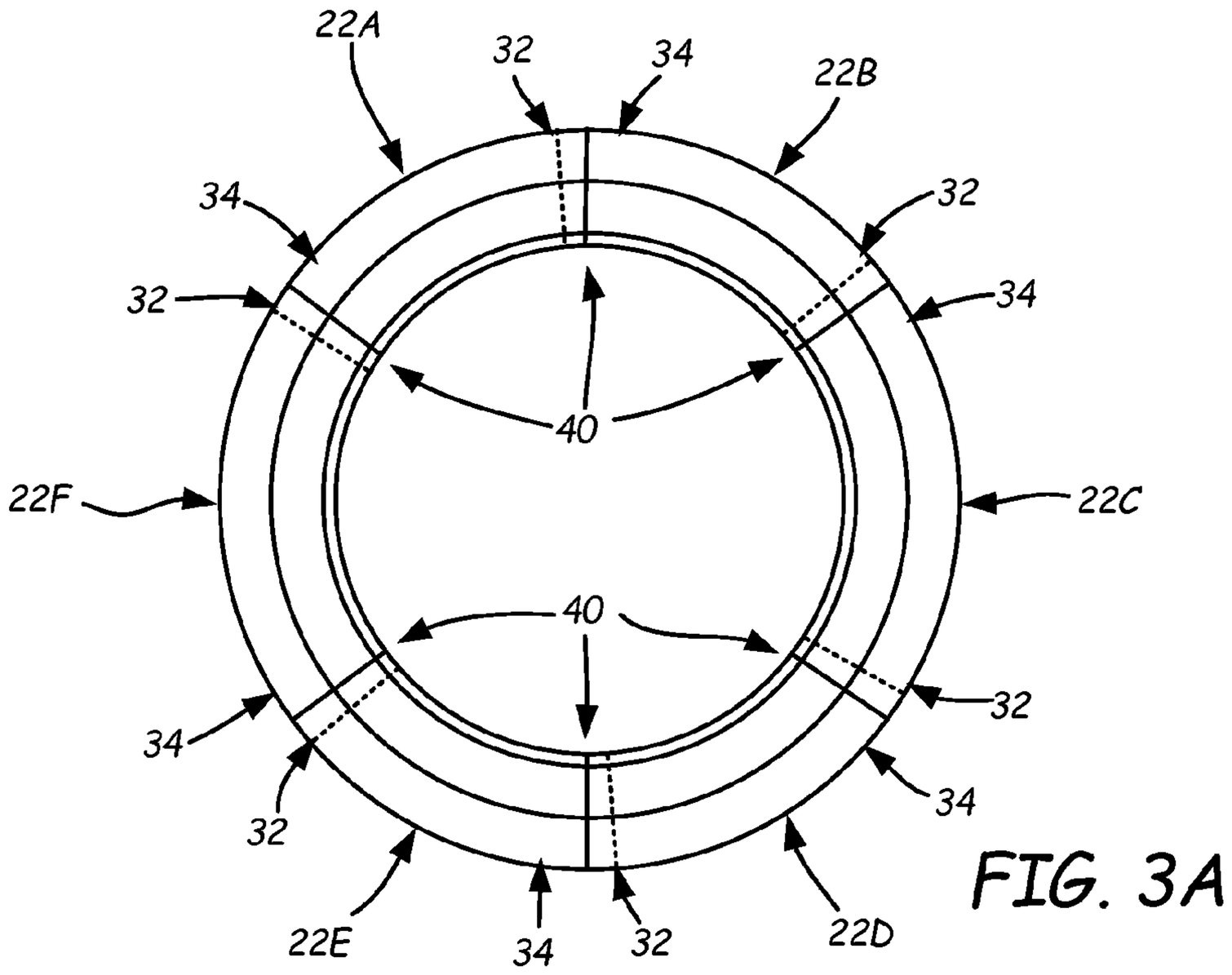

22A
32
34
22B
34
32
32
34
40
22F
22C
40
32
34
34
32
22E
34
32
22D

FIG. 3A

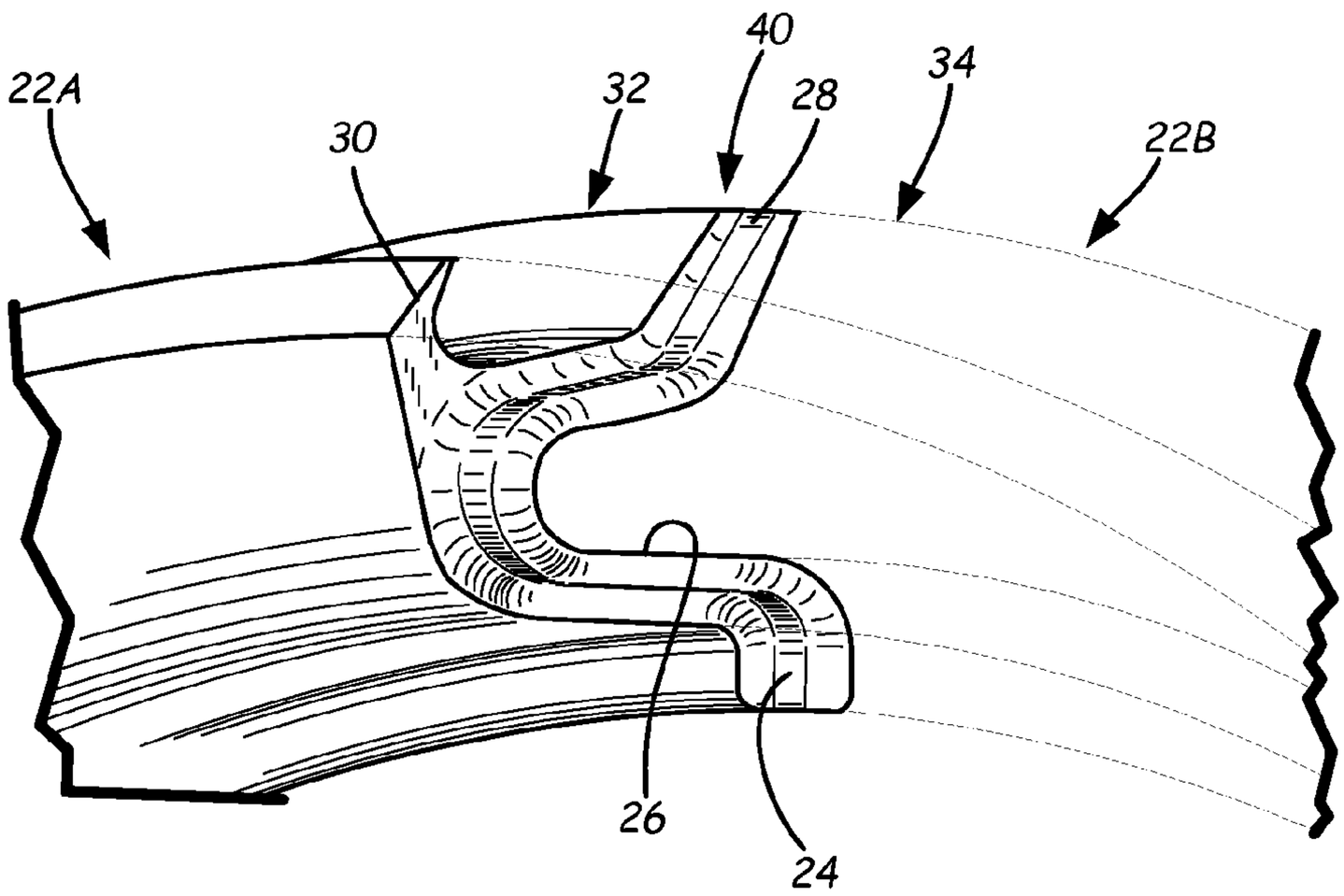

40
22A
32
28
34
30
22B
26
24

FIG. 3B

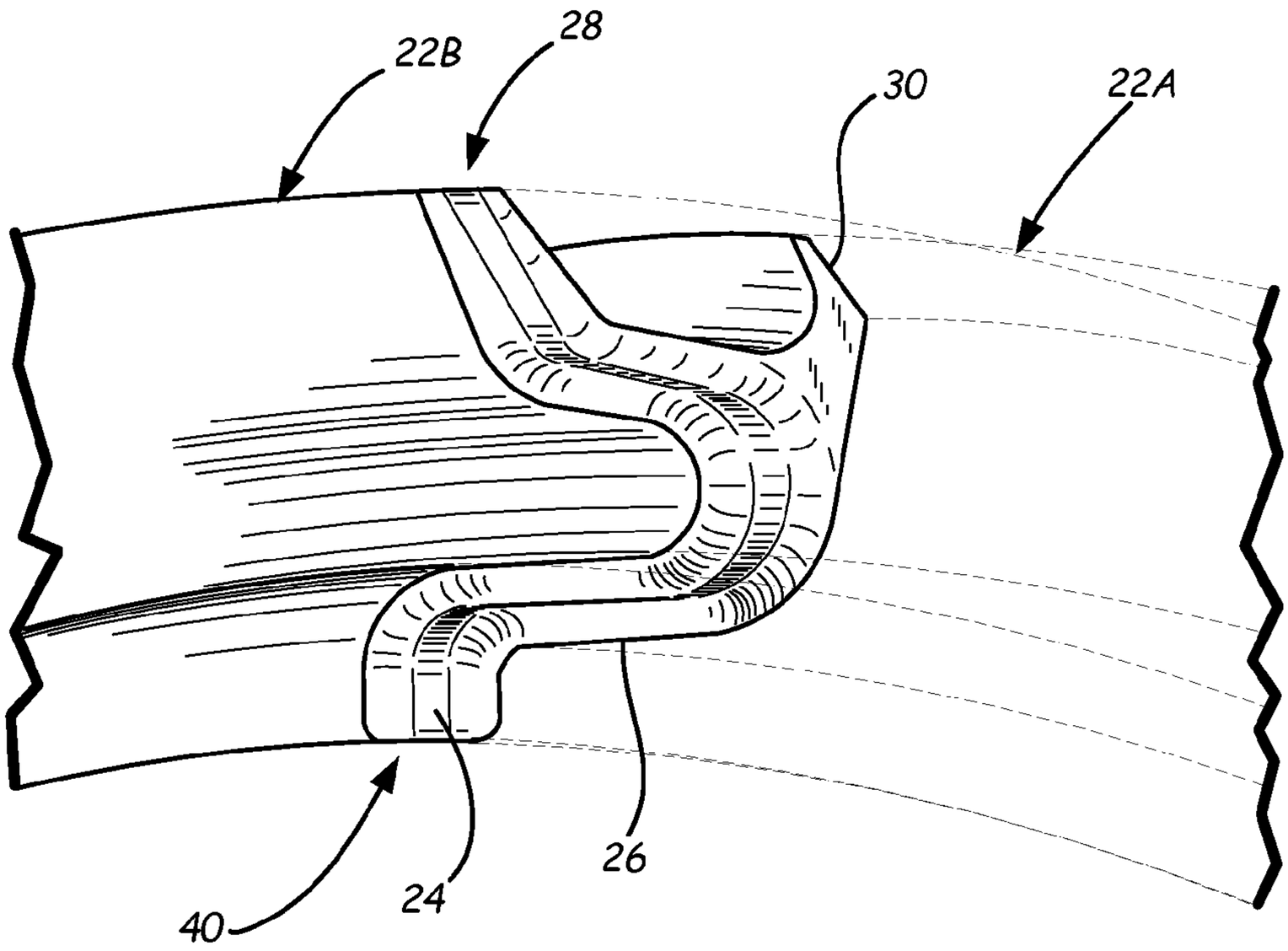


FIG. 3C

SEGMENTED SEAL WITH SHIP LAP ENDS

BACKGROUND

Knife edge seals are used in most rotors of a gas turbine engine to prevent gas from leaking around rotors and blades. Knife edge seals are particularly used in very hot areas, such as the high pressure compressor and high pressure turbine. A typical knife edge seal is a full hoop with a portion attaching to a rotor or blade and a knife edge which contacts another rotor, blade, casing or other part to prevent leakage.

SUMMARY

A segment for a knife edge seal includes an arcuate segment with a first end with a first end surface and a second end with a second end surface. The first end surface and the second end surface are complementary and overlapping when the first end surface and the second end surface interface with ends of adjacent segments.

A method of forming a segmented seal with ship lap ends includes obtaining a plurality of oversized arcuate seal segments, each segment with a first end and a second end with a second mating surface; machining the first end of each segment to form a first mating surface; machining the second end of each segment to form a second mating surface, wherein the first mating surface is complementary and overlapping to the second mating surface when a first end of a seal segment is interfaced with a second end of another adjacent seal segment; and fitting the segments together to form a full circumferential segmented seal, wherein the segments are fit together with a first mating surface of one segment connecting to a second mating surface of an adjacent segment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a cross-sectional view of a portion of a high pressure compressor.

FIG. **1**B is a perspective view of the hub, disk and a seal segment of FIG. **1**A.

FIG. **2**A is a perspective view of a first end of a seal segment.

FIG. **2**B is a perspective view of a second end of a seal segment.

FIG. **3**A shows a perspective view of seal segments arranged to form a full circumferential segmented seal.

FIG. **3**B shows the connection between two seal segments of FIG. **3**A, with a second seal segment shown as see through.

FIG. **3**C shows the connection between two seal segments of FIG. **3**A, with a first seal segment shown as see through.

DETAILED DESCRIPTION

FIG. **1**A is a cross-sectional view of a portion of a high pressure compressor **10**, and FIG. **1**B shows a perspective view of a portion of disk **12**, rear hub **16** and knife edge seal **20** of FIG. **1**A. The portion of high pressure compressor **10** shown includes rotor disk **12** with slot **13**, blade **14**, rear hub **16**, outlet guide vane **18** and knife edge seal **20**. Knife edge seal **20** is formed of a plurality of arcuate segments **22**, each including retention tang **24**, load bearing surface **26**, first knife edge **28**, second knife edge **30**, first end **32** and second end **34**.

Blade **14** connects to disk **12** at slot **13** to move with disk. Rear hub **16** connects to disk **12** to move with disk **12** as well. Knife edge seal **20** connects to rear hub **16** and disk **12** by retention tang **24**.

Disk **12**, blade **14**, rear hub **16** and knife edge seal **20** rotate together to move air through compressor section **10**, compressing the air. Knife edge seal **20** contacts and can slice into abradable material **21** to form a seal between rotating parts (disk **12** and rear hub **16**) and stationary parts (outlet guide vane **18**). This ensures most air flows through compressor **10** flows through exit guide vane **18** and not down near rear hub **16**. This increases efficiency by keeping compressed air in the primary flowpath.

Knife edge seal **20** is made of a plurality of arcuate segments **22** to form a full circumferential segmented seal (see FIG. **3**A) between rotating and non-rotating components. Segments **22** are generally shaped the same, with a first end **32** that is overlapping and complementary to second end **34** when connected. When an engine is in operation, disk **12**, blade **14**, rear hub **16** and knife edge seal **20** are rotating and centrifugal force acts on knife edge seal segments **22**, pushing them away from each other. By making ends **32**, **34** of segments **22** overlapping and complementary, knife edge seal **20** leakage is minimized or prevented between seal segments during all engine conditions.

FIG. **2**A is a perspective view of first end **32** of seal segment **22**, and FIG. **2**B is a perspective view of second end **34** of a seal segment **22**. Seal segment **22** includes retention tang **24**, load bearing surface **26**, first knife edge **28**, second knife edge **30**, first end **32** and second end **34**. Seal segments **22** are generally one monolithic part and can be made of nickel (including alloys) or other materials depending on system requirements, including, but not limited to weight and operating temperatures.

Seal segments **22** can be formed by obtaining a plurality of oversized seal segments. The segments must be oversized initially to be able to mill, or otherwise machine them down on first end **32** and second end **34** and once machined, be able to form a complete circle with all segments **22**. A path to form the ship lap seal through the segment **22** cross section must be chosen. This can be selected by separating the cross-section into halves, for example, an inner portion and an outer portion or an upper portion and a lower portion. The shiplap seal must form a path through the entire cross section of the seal **20** to be able to prevent leakage. First end **32** is then machined down to form one half of the seal with a first mating surface **33**. Next, second end **34** is machined down to form a complementary other half of the seal with a second mating surface **35**. Seal segments **22** can then fit together, with first mating surface **33** connecting to by facing or butting up against second mating surface **35** of adjacent seal segments **22** to form a full circumferential segmented knife edge seal **20**.

In the example shown in FIGS. **2**A-**2**B, outer half of first end **32** is machined down so that inner half extends further circumferentially. Inner half of second end **34** is machined down so that outer half extends further circumferentially to form complementary shapes. In the example shown, first end **32** is convex on inner half and second end **34** is concave on inner half. This enables segments **22** to fit together, first end **32** to second end **34** and form an overlapping ship lap seal between adjacent segments **22**.

Because knife edges **28**, **30** are very thin on knife edge seals **20**, manufacturing seal segments **20** can involve initially forming the knife edge which the shiplap seal will go through (in this example, first knife edge **28**) wider than desired. Ends **32**, **34** can then be machined down to form complementary overlapping ends between segments **22**.

FIG. **3**A shows a full knife edge seal **20**. FIG. **3**B shows an interface between two seal segments **22**A and **22**B, with seal segment **22**B shown as see through, and FIG. **3**C shows FIG. **3**B with a first seal segment **22**A shown as see through. Full

knife edge seal **20** is made of six segments **22**A, **22**B, **22**C, **22**D, **22**E and **22**F, with a ship lap seal **40** between each. Knife edge seal **20** includes first seal segment **22**A and second seal segment **22**B with shiplap seal **40**, each segment **22**A, **22**B with retention tang **24**, load bearing surface **26**, first knife edge **28**, second knife edge **30**, first end **32** and second end **34**. While six seal segments are shown, knife edge seal **20** could be formed by more or fewer segments in other embodiments to form a complete circumferential segmented knife edge seal **20**.

First end **32** of first seal segment **22**A fits complementary and overlapping with second end **34** of second seal segment **22**B. While only one shiplap seal **40** between segments **22**A, **22**B is shown, each shiplap seal **40** between adjacent seal segments in knife edge seal **20** includes a first end **32** which is complementary and overlapping to a second end **34**.

Knife edge seal **20** is formed by segments **22**A-**22**F. By forming ends **32**, **34** of each segment **22** to be overlapping and complementary, knife edge seal **20** is able to prevent leakage between seal segments **22**, making the seal more effective even during engine operating conditions when centrifugal force pushes seal segments **22** outward and away from each other. By overlapping to prevent leakage between segments **22**, seal **20** can protect engine parts and promote engine efficiency by directing air flow properly.

While a portion of high pressure compressor **10** is shown, knife edge seal **20** can be used in many other parts that need a seal between rotating parts and non-rotating parts, including, but not limited to the high pressure turbine and the low pressure compressor. While segmented seal **20** shown includes two knife edges **28**, **30**, other seals can contain more or fewer knife edges and can take a different path through the cross-section for the overlapping portions.

While knife edge seal **20** has been discussed in relation to being formed of segments **22**, each with a first end and a second end that are overlapping and complementary, segment ends could be varied so long as the connection between two adjacent segments is complementary and overlapping.

A segment for a knife edge seal includes an arcuate segment with a first end with a first end surface and a second end with a second end surface; wherein the first end surface and the second end surface are complementary and overlapping when the first end surface and the second end surface interface with ends of adjacent segments.

Additional and/or alternative embodiments include the first end surface and the second end surface having a convex portion and a concave portion; the transition between the convex portion and concave portion going through the knife edge of the seal; the segment comprising a retention tang to hold the seal in place, a knife edge, and a main load bearing surface to connect the retention tang and the knife edge; the transition between the convex and concave portion going through the tang, the main load bearing surface and the knife edge; the overlap being 10% of the seal length; the seal being made of nickel; and/or the segment fitting end to end with one or more other segments to form a full circumferential segmented knife edge seal.

A segmented knife edge seal includes a plurality of knife edge seal segments, wherein the segments fit together to form a full segmented circle. Each segment comprises a knife edge; a first end; and a second end, wherein the first end and the second end are complementary so that the end of each segment mates with the second end of an adjacent segment to overlap and form a ship lap seal between adjacent segments.

Additional and/or alternative embodiments include the first end of each segment extending circumferentially further on a top half of the segment than a bottom half; the second end of each segment extending circumferentially further on a bottom half of the segment; the ship lap seal extending through the knife edge; the segments being nickel, the segments overlapping each other 20% of the length, each segment further comprising a retention tang to hold the seal in place with respect to another part and a main load bearing surface to connect the retention tang to the knife edge; and/or the ship lap seal going through the retention tang, the main load bearing surface and the knife edge.

A method of forming a segmented seal with ship lap ends includes obtaining a plurality of oversized arcuate seal segments, each segment with a first end and a second end with a second mating surface; machining the first end of each segment to form a first mating surface; machining the second end of each segment to form a second mating surface, wherein the first mating surface is complementary and overlapping to the second mating surface when a first end of a seal segment is interfaced with a second end of another adjacent seal segment; and fitting the segments together to form a full circumferential segmented seal, wherein the segments are fit together with a first mating surface of one segment connecting to a second mating surface of an adjacent segment.

Additional and/or alternative embodiments include the step of machining the first end and second end of each seal segment so that it is complementary and overlapping when a first end of a seal segment is connected to a second end of another adjacent seal segment comprising machining the first end of each segment so that an outer portion of the first end extends further circumferentially than an inner portion and machining the second end of each segment so that an inner portion of the second end extends further circumferentially than an outer portion, wherein after machining, the first end of each segment fits together with the second end of any segment to form a ship lap seal between segments; the seal being a knife edge seal and the machining being performed on the first end and second end so that the ship lap seal extends through the knife edge seal.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method of forming a segmented knife edge seal with ship lap ends, the method comprising:

obtaining a plurality of oversized arcuate seal segments, each segment with a first end, a second end, a retention tang to hold the seal in place with respect to another part, and a main load bearing surface to connect the retention tang to the knife edge seal, the first and second ends spaced apart in a circumferential direction;

machining the first end of each segment to form a first mating surface for a ship lap seal, wherein machining is performed on the first end so that the ship lap seal extends through the knife edge seal, and wherein the first end has a convex portion and a concave portion;

machining the second end of each segment to form a second mating surface for another ship lap seal, wherein machining is performed on the second end so that the other ship lap seal extends through the knife edge seal, wherein the first mating surface is complementary and

overlapping to the second mating surface when a first end of a seal segment is interfaced with a second end of another adjacent seal segment, and wherein the second end has a convex portion and a concave portion, the respective concave and convex portions of the first and second ends defining the complementary ship lap mating surfaces; and

fitting the segments together to form a full circumferential segmented seal, wherein the segments are fit together with the first mating surface of one segment connecting to the second mating surface of an adjacent segment.

2. The method of claim **1**, wherein the step of machining the first end and second end of each seal segment so that it is complementary and overlapping when a first end of a seal segment is connected to a second end of another adjacent seal segment comprises:

machining the first end of each segment so that an outer portion of the first end extends further circumferentially than an inner portion; and

machining the second end of each segment so that an inner portion of the second end extends further circumferentially than an outer portion, wherein after machining, the first end of each segment fits together with the second end of any segment to form a ship lap seal between segments.

3. A segment for a knife edge seal comprising:

an arcuate segment defining a portion of a circle, the arcuate segment having a first end with a first end surface, a second end with a second end surface, a retention tang to hold the seal in place, and a main load bearing surface to connect the retention tang and the knife edge; wherein the first end surface and the second end surface are circumferentially spaced from each other, and wherein the first end surface and the second end surface each define a rabbeted ship lap mating surface that goes through a knife edge of the seal, wherein both the first end surface and the second end surface have a convex portion and a concave portion, which define the respective rabbeted ship lap mating surfaces.

4. The segment of claim **3**, wherein a transition between the convex and the concave portion goes through the tang and the main load bearing surface.

5. The segmented seal of claim **3**, wherein the rabbeted ship lap mating surface of the both the first and second ends defines an overlap that is 10% of the seal length.

6. The segmented seal of claim **3**, wherein the seal is made of nickel.

7. The segmented seal of claim **3**, wherein the segment fits end to end with one or more other segments to form a full circumferential segmented knife edge seal.

8. A segmented knife edge seal comprising:

a plurality of knife edge seal segments, wherein the segments fit together to form a full segmented circle, each segment comprising:

a knife edge;

a retention tang to hold the seal in place with respect to another part;

a main load bearing surface to connect the retention tang to the knife edge;

a first end; and

a second end circumferentially spaced from the first end, wherein the first end and the second end are complementary so that the first end of each segment mates with the second end of an adjacent segment to overlap and form a ship lap seal between adjacent segments, wherein the ship lap seal extends through the knife edge, and wherein both the first end and the second end have a convex portion and a concave portion, which define the complementary ship lap mating surfaces of the first and second ends.

9. The segmented knife edge seal of claim **8**, wherein the first end of each segment extends circumferentially further on a top half of the segment than a bottom half.

10. The segmented knife edge seal of claim **9**, wherein the second end of each segment extends circumferentially further on a bottom half of the segment.

11. The segmented knife edge seal of claim **8**, wherein the segments are nickel.

12. The segmented knife edge seal of claim **8**, wherein the segments overlap each other about 20% of each segment length.

13. The segmented knife edge seal of claim **8**, wherein the ship lap seal goes through the retention tang and the main load bearing surface.

* * * * *